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OPTICAL FIBER TESTING.(U)

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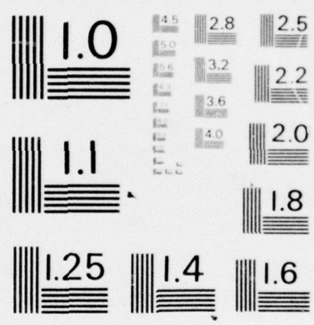

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DEPARTMENT OF MINING, METALLURGICAL, AND CERAMIC ENGINEERING
SEATTLE, WASHINGTON 98195

Contract N00123-73-C-1200

Principal Investigators

JAY H. HARRIS

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Task 002 Final Report for the Period Ending
31 October 1973

OPTICAL FIBER TESTING

W. D. Scott, G. Achutaramayya

30 November 1973

Principal Investigators

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Construction of a fiber pulling machine for producing special fibers is described. Results of strength tests on fibers are presented.

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TO: Naval Electronics Laboratory Center
San Diego, California
Contract No. N00123-73-C-1200

SUBJECT: Task U/W 002
Technical Report for Task Completion
Period of Performance 4/30/73 to 10/31/73

During the performance period of this task, work was carried out in the following three general areas: (1) Fracture testing of optical fibers, (2) Construction of a fiber pulling machine, and (3) Fabrication of special fiber and waveguide configurations.

1. Fracture Testing

A. After considerable review and consideration of many different methods of measuring the tensile strength of very small glass fibers, the technique described by Hill and Lee (1) was selected. The main difficulties in this type of testing are in gripping the ends of the fibers, supporting the fiber and keeping it intact while mounting in the testing machine, and obtaining exial alignment during testing. The device shown in Fig. 1 was constructed and was used to measure the tensile strength of unclad silica fibers obtained from Bell Telephone Laboratories. Typical results of these tests are shown in Table I.

The fibers tested thus far were as-received fibers which had been made, stored and handled without special safeguards against accidental damage. The results show the large variation in strength to be expected when random surface damage is present on the fiber specimens. The high strength values obtained in a few cases show that the testing technique itself does not introduce weakening effects.

Another goal in this task was to develop techniques for the examination of fracture surfaces to relate fracture behavior and defects or damage in the glass. When the fracture stress was high, the fiber usually shattered into many fragments so that identification of the fracture origin was impossible. In a few cases where the fracture strength was low, the specimen broke into only a few pieces, and the initial fracture point could be located and examined. On typical result is shown in Fig. 2 where the fracture origin may be identified with a surface defect about 1.3 by 0.6 microns. One of the primary goals in future work on fracture is to investigate the low strength locations in fibers, i.e. the defects which may cause unexpected failures at very low stresses. Intense shattering should not occur under these conditions so it is anticipated that the fracture point can be identified and examined.

The shattering of high strength specimens is caused by reflections and interference of shock waves in the specimen. A slight modification of the test jig would permit testing in a fluid which may provide some damping and reduce shattering.

Future work, outlined in Task 004 includes further tests on short lengths, coating of as-drawn fibers to prevent surface damage and development of facilities for long length testing.

2. Construction of the Fiber Pulling Machine

The basic design for the fiber pulling machine was adapted from the Bell Telephone Laboratory device illustrated in Ref. (2). The basic criteria in design of the pulling device were to make it as rigid and precise as possible to insure uniform fibers. In addition it was desired to have the capability of pulling a variety of glasses with

different working temperatures up to that of fused silica at 2000°C. A schematic diagram of the machine constructed at the University of Washington is shown in Fig. 3. The following features are incorporated in this apparatus.

A. Furnacing:

Induction heating of rod and tube preforms will be employed with the following two systems which are complete.

1. Platinum suceptor 1" ID x 1" long capable of 1500°C in air.
2. Graphite suceptor 3/4" ID x 1" long capable of 2000°C in inert atmosphere. Double walled water cooled glass container with provision for preform feed, gas flow and fiber egress.

B. Stand

Rigid stand with variable speed feed device located up to 7' above the winding drum. The large head room is to facilitate coating or sampling the fiber before it touches any surface.

C. Winding Drum

Pricision machined winding drum 11" diameter (concentric to within 0.0003 inches) and 15 inches long. The drum traverses horizontally 1/2 mm per revolution to wind the fiber and keep the pulling position constant. The unit is driven by a variable speed D.C. motor.

D. Take-off Drum

A separate drum with induction motor drive. This drum is made from a heavy replaceable paper tube and is used to remove and store the fiber from the pulling drum. One hundred fifty such storage drums are on hand.

The pulling device is in the final stages of assembly and will be operational by December 1, 1973.

3. Fabrication of Special Waveguide and Fiber Configurations

In cooperation with the group working on Tasks 001 and 003 of this contract, some effort was made to produce some special waveguide configurations.

Unsuccessful attempts were made to produce a small scale periodic structure by drawing down a larger structure cut into a glass slide.

Another structure which was successfully produced was a single fiber bonded to a glass plate. The bonding was accomplished by heat treatment at 650°C for 6 hours. The operation is sensitive to time and temperature, especially temperature, if a rounded fiber is to be maintained.

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1. N. A. Hill and S. A. Lee, "A Simple Apparatus for the Axial Loading of Brittle Rods and Fibers", proc. Brit. Ceram. Soc.; No. 15, January 1970, pp. 85-89.

2. A. D. Pearson and W. G. French, "Low-Loss Glass Fibers for Optical Transmission", Bell Lab Record, Vol. 50, April 1972, pp. 102-109.

TABLE I

Typical Tensile Strength of Unclad Silica Fibers
(Diameter of Fiber = 140 μm)

Test No.	Fiber Length (cm)	Tensile strength* Kpsi	Type of fracture
1	22	24.8	Single
2	23	29.0	Single
3	23	48.5	Shattered
4	23	31.2	Double
5	23	15.5	Triple
6	21	26.5	Triple
7	24	18.5	Shattered
8	24	21.3	Single
9	25	37.0	Shattered
10	25	22.6	Double
11	24	31.0	Shattered
12	23	31.9	Shattered
13	26	25.4	Shattered
14	24	16.0	Single
15	19	32.5	Shattered
16	22	40.2	Shattered
17	23	47.9	Shattered
18	23	19.6	Single

*Tested at a strain rate of 0.01 cm/min.

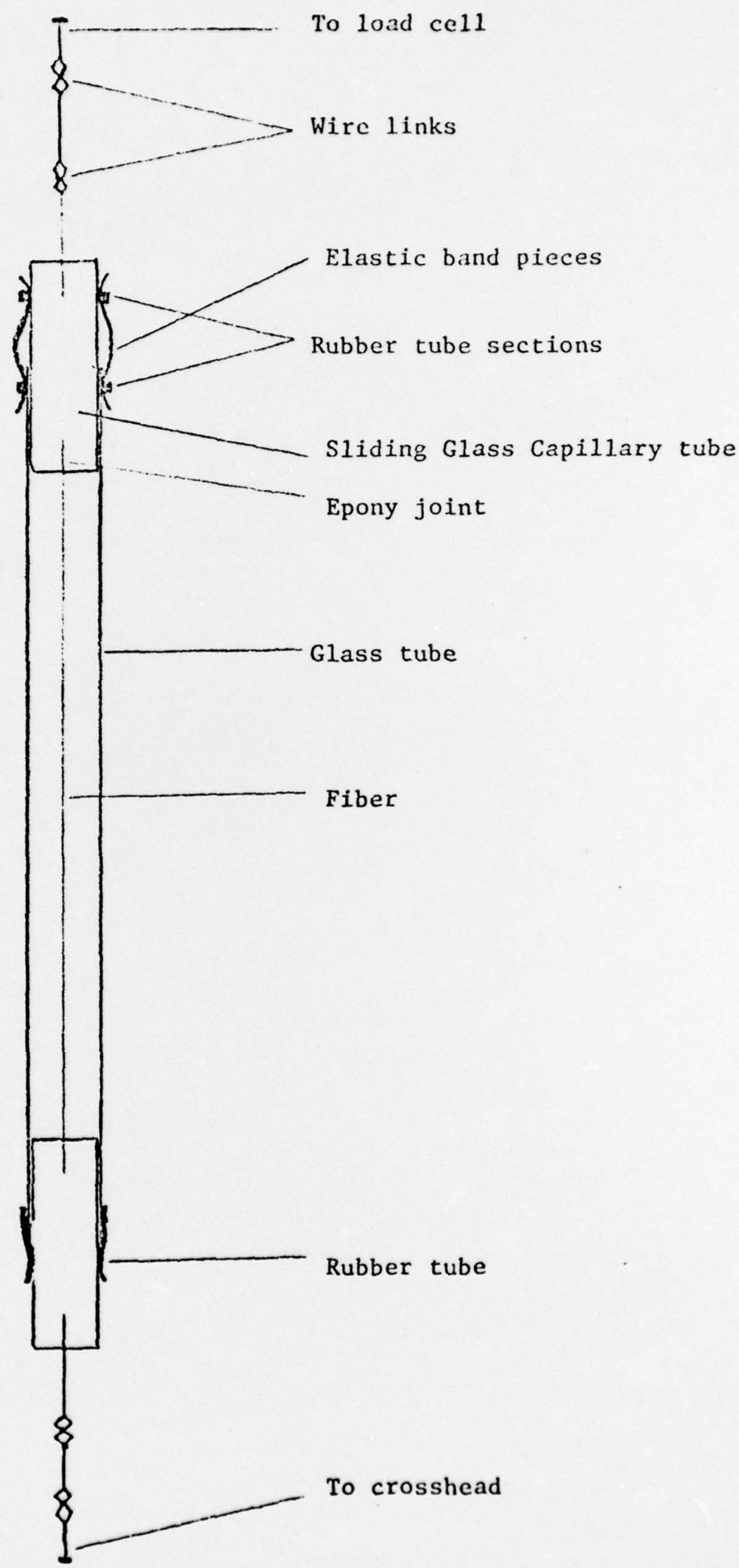
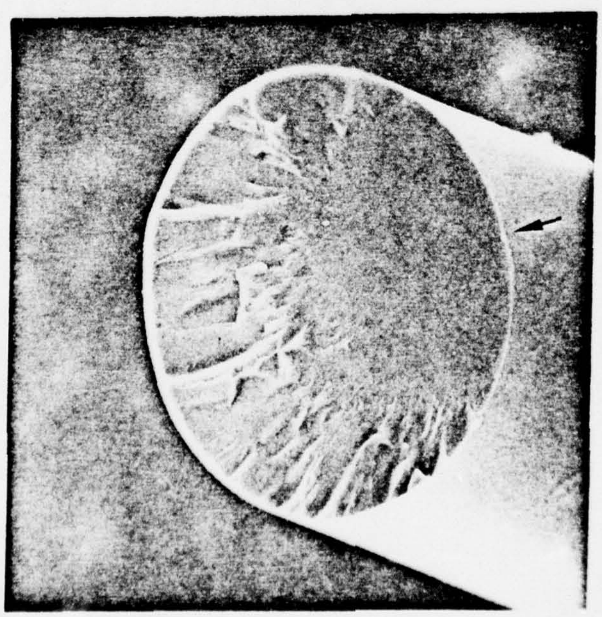


Figure 1. Tensile testing apparatus.

Figure 2. SEM picture of fracture surface of silica fiber. The arrow indicates the fracture origin. The magnification on the left picture is 600 X. The fracture origin is magnified in the right picture to 12000 X.



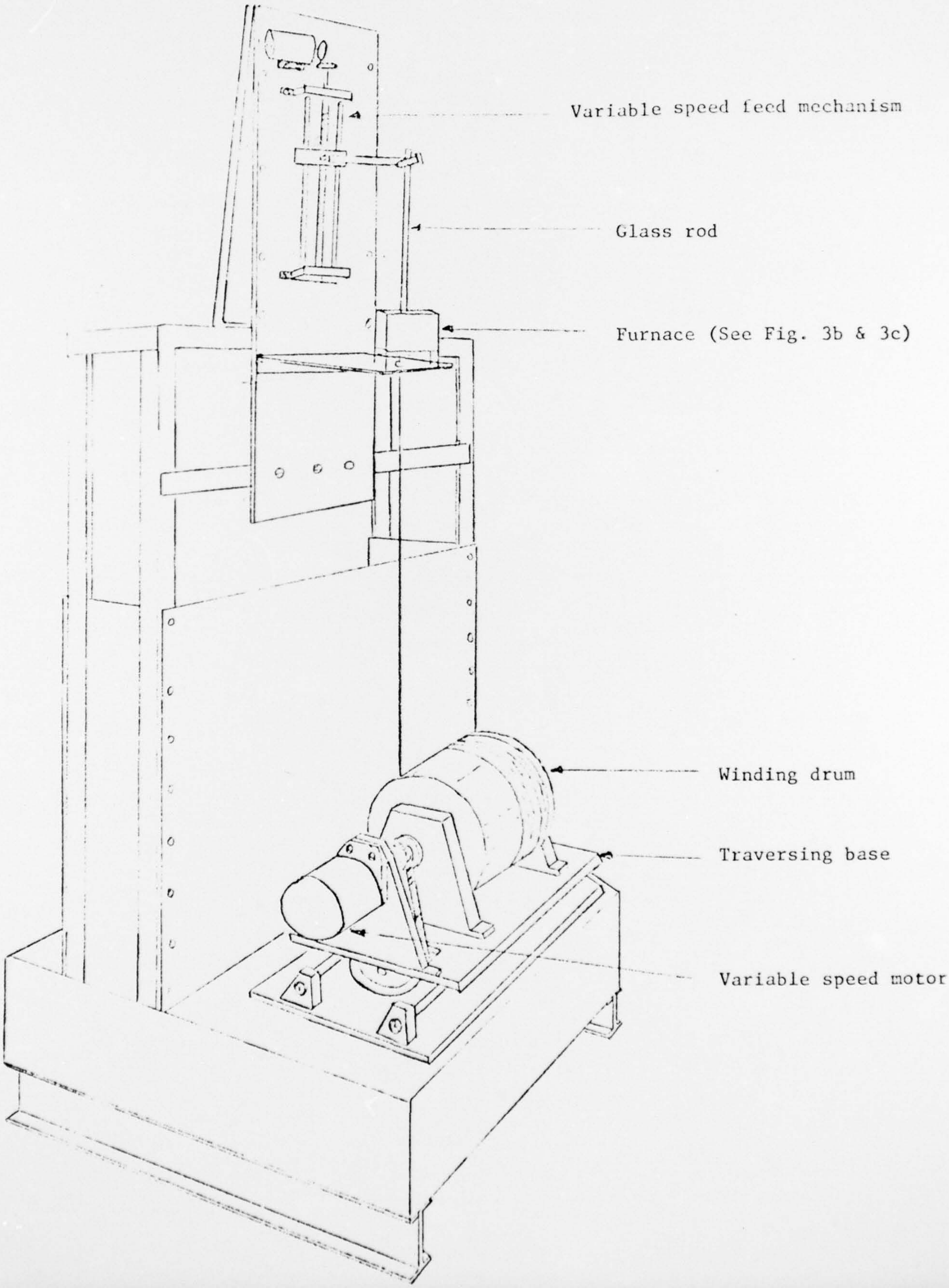


Figure 3a. Fiber drawing unit

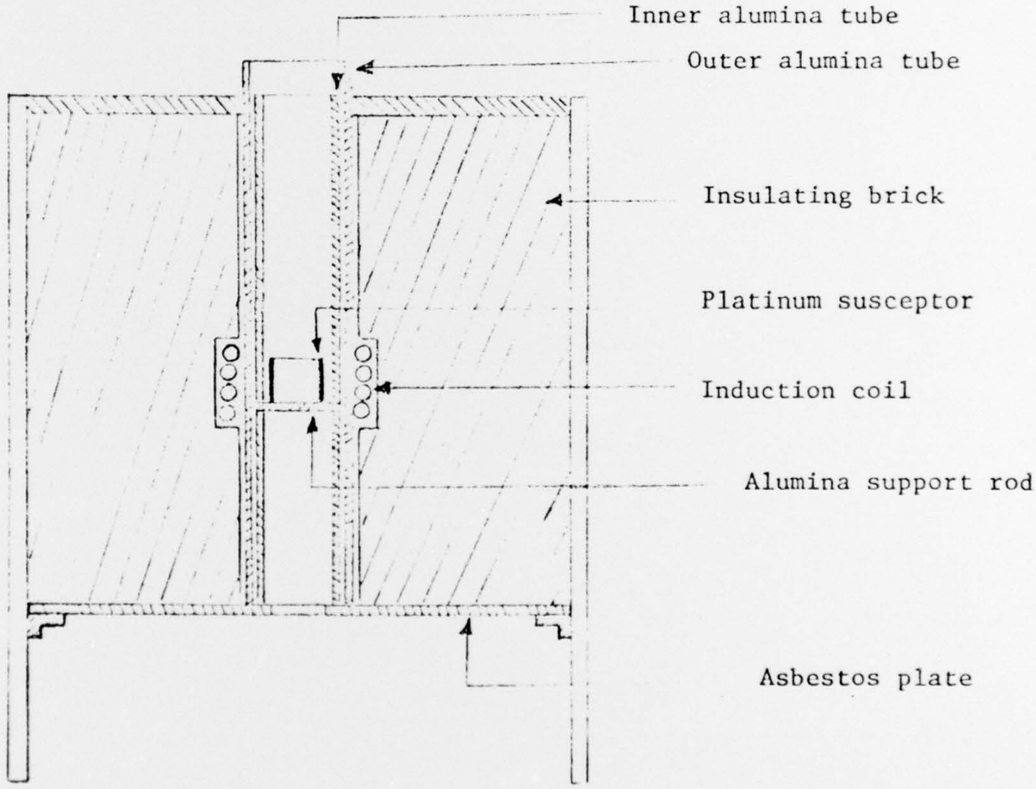


Figure 3b. Schematic of platinum induction furnace to operate up to 1500°C in air.

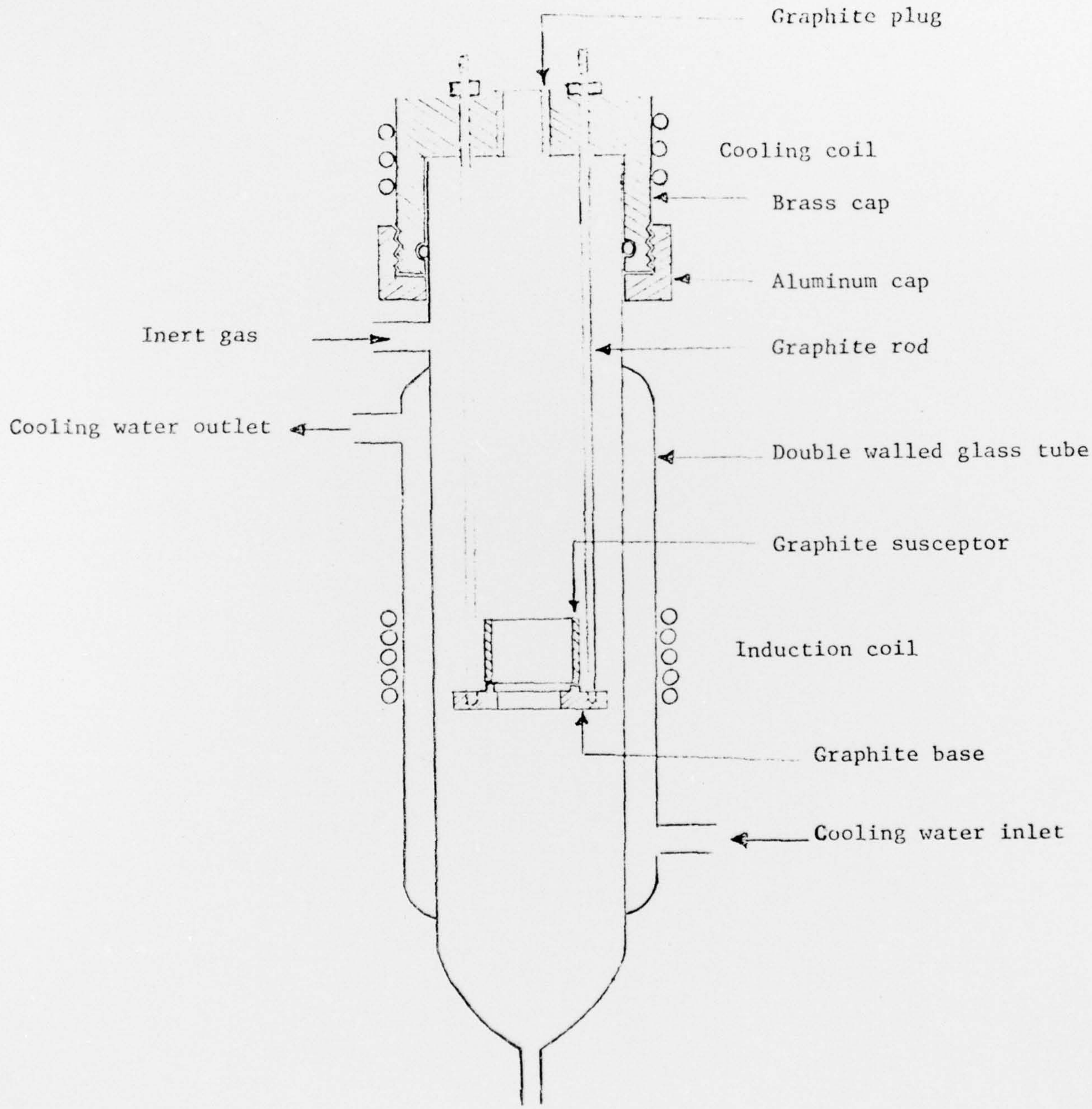


Figure 3c. Schematic of graphite induction furnace to operate at 2000°C.